Comparison of Interannual Intrinsic Modes in Hemispheric Sea Ice Covers and Other Geophysical Parameters

Per Gloersen and Norden Huang

Abstract

Recent papers have described 18-year trends and intradecadal oscillations in the Arctic and Antarctic sea ice extents, areas, and enclosed open water areas based on newly formulated 18.2-year ice concentration time series. They were obtained by fine-tuning the sea ice algorithm tie points individually for each of the four sensors used to acquire the data. In this paper, these analyses are extended to an examination of the intrinsic modes of these time series, obtained by means of Empirical Mode Decomposition, with emphasis on periodicities greater than the annual cycle. Quasibiennial and quasiquadrennial oscillations similar to those observed with a multitaper-filtered Fourier analysis technique and reported earlier for the first 8.8 years of this time series were also observed in the present series. However, the intrinsic modes were not monochromatic; they feature frequency as well as amplitude modulation within their respective frequency bands. The slowest-varying mode in the Antarctic sea ice cover has slightly less than a full period during this 18.2-year time period, but the change in sign of its curvature hints at a modal period of about 19 years, with important implications for the trend analyses published earlier.

Index Terms: geophysical measurements, microwave measurements, remote sensing, sea, sea ice.

variations in the Arctic sea ice cover has been suggested [32], at least that portion connected to the North Atlantic and the variations in the North Atlantic Oscillation (NAO). We constructed a low-pass (LP) filter by combining the modes with periods longer than that of the seasonal cycle for each entity. Fig. 9 and Table 1 show the results of this endeavor.

In the Arctic, the sea ice areas and extents vary in phase, albeit with differing amplitudes, with a maximum cross-correlation coefficient of 0.90 at a lag of 0 years (Table 1.). Despite their amplitude differences, the LP-filtered extent and area series are similar enough to imply that these oscillations are typical of the entire pack and not just the marginal ice. This may diminish ocean-ice boundary interactions and favor interactions between the ice and the atmosphere or underlying ocean as the source of the oscillations. In the Antarctic, however, they are in phase only up to 1984, after which the extent appears to lag the area by several months, perhaps because of stronger ocean-atmosphere interactions near the ice margin compared to its interior. Here, the cross-correlation coefficient over 18 years is only 0.59, with the extent lagging the area by 0.2 years.

In Fig. 9, it is difficult to visualize any correlations between NAO and the Arctic sea ice extents. In Table 1, the maximum cross-correlation coefficients 0.5`for the entire 18-year period, with the extents lagging the NAO by about 2.5 years. The areas also lag the NAO by about 2.5 years, but with an even lower cross-correlation coefficient of 0.43.

The anticorrelation between LOD and SOL is visually striking up until 1984 (Fig. 9.) with the cross-correlation coefficient being -0.62 and the LOD lagging the SOI by about 0.2 years (Table 1.). Subsequently, the anti-correlation is more difficult to visualize, and the 18-year cross-correlation coefficient drops to -0.48 and the lag to about 0.1 years. (The lags are negative in Table 1 because of the order used of the variables in the cross-correlation procedure.

The maximum cross-correlation coefficient during this period for the Antarctic sea ice area and the LOD is 0.4, with the area lagging the LOD by about 2 years (Table 1.). The coefficient is even lower between the extents and LOD, 0.33 with a lag of about 2.5 years. Thus the influence of the LOD (and, by inference the SOI) on the Antarctic sea ice coverage is not as robust as imagined earlier, based on comparisons of Fourier spectra.

We originally thought that variations in the solar irradiance (Fig. 9.) might be reflected in the global sea ice coverage, i.e., the sum of the Arctic and Antarctic sea ice areas. However, the maximum cross-correlation coefficient is the lowest in Table 1, 0.26, and not of the sign expected. The coefficient is even lower and also with an unexpected sign when comparing solar irradiance with the Antarctic area by itself.

In summary, prior intercomparisons between time series from different phenomena were done mostly by comparing their Fourier spectra, or by casual visual observations. The results we present here, based on intercomparison of instantaneous values of oscillatory amplitudes and phase, indicate that the relationships between the different phenomena studied here and earlier are not as robust as was implied by some of the earlier studies. We believe that future intercomparisons between geophysical entities should take into account their likely nonstationarity, and should be analyzed with the use of a filtering technique such as EMD that can accommodate nonstationarity.

V. Discussion

In earlier papers [8]-[12], the various authors suggested by inference a connection between the ENSO and sea ice variations in certain regions of both hemispheres. The inference depended upon the similarity of their average periodograms. In order for the comparison of periodograms of this sort to be valid, the phenomena under investigation must be stationary. In this paper, we have shown that the phenomena reported earlier are, in fact, non-stationary, and hence the earlier average periodograms were perhaps over interpreted. EMD presents an efficient means for removing the seasonal cycle and shorter periodicities from the oscillations of the various phenomena, and we have demonstrated that data so filtered for purposes of comparison shows promise of identifying coupled phenomena.

Knowing that sea ice is driven by, among other things, a combination of atmospheric events (e.g., near-surface winds and sea-level pressures) and sea surface temperatures, we plan in the future to apply EMD to those gridded fields of observational data near the ice edge and to the gridded sea ice concentrations, in search of similar oscillatory structures and a viable correlation on a more localized basis. While we have no model to support this hypothesis, it may be that the ice canopies have some inherent natural resonance frequencies that can be excited by impulsive input. We already know that the Antarctic Circumpolar Wave is present in some atmospheric fields [34] and in the sea ice [34]-[35], and that it is but loosely connected to the ENSO. We shall report on these subsequent activities in a later paper.

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